

Title: Quantification of Neutral Wind Variability in the Upper Thermosphere

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Final Report:

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The overall objective of this grant was to quantify thermospheric neutral wind behavior in the ionosphere. This was to be achieved by developing an improved empirical wind model, 2) validating the procedure for obtaining winds from the height of the peak density, 3) improving the model capabilities and making updated versions of the model available to other scientists. The approach is to use neutral winds derived from ionosonde measurements of the height of the peak electron density ($h_m F_2$). One of the proposed first year tasks was to perform some validation studies on the method. Substantial progress has been made with regard to both the empirical model and the validation study. Funding from this grant has also enabled a number of fruitful collaborations with other researchers; one of the stated aims in the proposal. Thirteen papers that acknowledge support from this grant are listed below.

Graduate student Mayra Martinez has developed the mathematical formulation for the empirical wind model as part of her dissertation. She is following the vector spherical harmonic approach that has been employed by Dr. Alan Hedin who has recently retired. This work is proceeding on schedule and we are currently modeling global wind data from 1986. Mayra should obtain her Ph.D. in December 2000. Mayra has also compared between neutral winds from radar ion velocities, FPI optical Doppler shift, and $h_m F_2$ techniques using data from Millstone Hill. We have shown that there is better agreement between the radar and $h_m F_2$ winds than between the optical and other measurements. The problem is particularly acute when the optical measurements have large error bars. This study calls into question the utility of the $O^+ - O$ collision frequency that has been derived from the Millstone Hill data.

As proposed, we have continued validation studies of the technique for determining winds from $h_m F_2$. We submitted a paper to the Journal of Geophysical Research in December 1996 entitled "*Thermospheric neutral winds at southern mid-latitudes: comparison of optical and ionosonde $h_m F_2$ methods.*" We refined the paper with additional tests at the request of the reviewers and the paper was published in the December 1997 issue of JGR. This paper presents a comparison of neutral winds measured by a ground-based optical method with winds derived from digisonde measurements of the peak height of the F_2 layer ($h_m F_2$) derived by true height inversion. The results are from a campaign near Melbourne, Australia during the first six days of March 1995. A group headed by Dr. Peter Dyson at La Trobe University made the measurements and we provided the modeling expertise. Remarkably good agreement is found between the two methods for obtaining winds. In collaboration with Dr. Dyson, we are performing similar studies for several other data sets. He presented these new results at the COSPAR meeting in Japan in July of 1998.

A second paper entitled "*Ionospheric behavior at a southern mid-latitude in March 1995*" has come out of the March 1995 data set and was published in The Journal of Geophysical Research. The March 1995 period was magnetically active with both negative (decrease) and

positive (increase) phases in the electron density variation. We have simulated the electron density variation with our FLIP ionosphere model. The standard FLIP model reproduces the positive phase very well. There is also a negative phase in the model at the appropriate time but it is not as pronounced as in the data. This study also showed a comparison between modeled and measured winds, neutral temperatures, and emission rates. This study is important because the determination of neutral winds may be affected by the assumed neutral composition.

A new algorithm was developed during the previous reporting period to modify the MSIS model exospheric temperature in order to improve the agreement between modeled and measured electron density. This modified T_n was about 100°K higher than the MSIS model and the measured T_n but the time variation followed the measurements reasonably well on several nights. At the suggestion of the reviewers, a number of improvements were made during the current reporting period.

We have also been modeling the ionosphere in the November 1993 space weather event. A paper entitled *"The ionosphere and thermosphere at a southern mid-latitudes during the November 1993 ionospheric storm: A comparison of measurement and modeling,"* by P. G. Richards, and P. J. Wilkinson was published. This paper examines the thermospheric wind behavior during the November 1993 magnetic storm that had a major impact on the ionosphere in the Australia-Japan region. At the peak of the storm, $h_m F_2$ increased rapidly and simultaneously at all stations probably as a result of the penetration of a magnetospheric electric field to low latitude. The sudden uplifting of the layer immediately produced a positive storm phase, which was followed by a negative phase on the day following the storm. Following the storm, the neutral winds were about 50-100 m/sec more equatorward than on the quiet days. One interesting feature of the neutral winds was the clear signature of the semidiurnal tide at all latitudes during the magnetically quiet periods with the peak amplitude occurring about 2 hours later at Hobart than at Townsville. In the current reporting period we performed a spectral analysis on the winds at Hobart, Townsville, and Canberra. We found that over a 14 day period, the semidiurnal amplitude was larger than the diurnal component at Townsville. The amplitude diminished with latitude until the diurnal component was dominant at Hobart. However, during November 1-3, the semidiurnal component was large at all 3 stations.

This grant was also aimed at providing access to our sophisticated ionospheric model called the Field Line Interhemispheric Plasmasphere (FLIP) model which has been freely available to other researchers for many years in a VMS version. In the past year we have been able to make available a unix version also. This model has been widely used for many years and has been installed at many locations throughout the world including, Chile, Brazil, Australia, Belgium, Spain, France, Japan, and many locations in the US. We have had particularly close ties with Dr. Horwitz's UAH group which is in the process of developing hybrid models of the auroral ionosphere and magnetosphere. The FLIP model forms the basis of the auroral models. In September, 1999, Dr. Ximena Torres came from Chile as a visiting scientist to learn how to use the FLIP model in her studies. She has now returned to Chile to continue her studies.

One of the problems with determining winds from $h_m F_2$ is possible contamination from convection electric fields. In fact, the wind determined from $h_m F_2$ is called an equivalent or effective wind because of the electric field component. A major development in the past year has been the incorporation of electric fields into the FLIP model. With this new model, we were able to show that electric fields do not play an important role in the anomalous nighttime behavior of the quiet ionosphere at Millstone Hill. This work has passed the review stage and is currently in

press in a paper titled "On the relative importance of convection and temperature on the behavior of the ionosphere in North America during January, 6-12, 1997".

LIST OF REFEREED ACKNOWLEDGED PUBLICATIONS FOR GRANTS NAG5-6053 and NAGW-4455:

1. "On the Causes of the Annual Variation in the Plasmaspheric Electron Density," P. G. Richards, T. Chang, R. H. Comfort *J. Atmos. Solar Terr. Phys.*, in press, January, 2000.
 2. "On the relative importance of convection and temperature on the behavior of the ionosphere in North America during January, 6-12, 1997," P. G. Richards, M. J. Buonsanto, B. W. Reinisch, J. Holt, J. A. Fennelly, J. L. Scali, R. H. Comfort, G. A. Germany, J. Spann, M. Brittnacher, and M.-C. Fok, *J. Geophys. Res.*, 105, in press, January, 2000.
 3. "Dynamic fluid-kinetic (DyFK) modeling of auroral plasma outflow driven by soft electron precipitation and transverse ion heating," X.-Y. Wu, J. L. Horwitz, G. M. Estep, Y.-J. Su, D. G. Brown, P. G. Richards, and G. R. Wilson, *J. Geophys. Res.*, 104, 17263-17275, 1999.
 4. "Comparison of neutral winds derived from airglow and ionosonde measurements," S. M. Ujmaia, P. L. Dyson, M. L. Parkinson, T. P. Davies, and P. G. Richards, *Adv. Space Res.* 24, (11), 1459, 1999.
 5. "Dynamic Fluid-Kinetic (DyFK) model for ionosphere-magnetosphere plasma transport: effects of ionization and thermal electron heating by soft electron precipitation," G. M. Estep, J. L. Horwitz, Y.-J. Su, P. G. Richards, G. R. Wilson, and D. G. Brown, *Terr. Atmos. Ocean. J.*, 10, 491 1999.
 6. "Comparison of models and data at Millstone Hill during the June 5-11, 1991, storm," Pavlov, A. V., M. J. Buonsanto, A. C. Schlesier, and P. G. Richards, *J. Atmos. Solar Terr. Phys.*, 61, 263-279, 1999.
 7. "The behavior of the ionosphere and thermosphere at a southern mid-latitude station during magnetic storms in early March 1995," P. G. Richards, P. L. Dyson, T. P. Davies, M. L. Parkinson, and A. J. Reeves, *J. Geophys. Res.*, 103, 26,421, 1998.
 8. "The ionosphere and thermosphere at southern mid-latitudes during the November 1993 ionospheric storm: A comparison of measurement and modeling," P. G. Richards, and P. J. Wilkinson, *J. Geophys. Res.*, 103, 9373, 1998.
 9. "Intercomparison of physical models and observations of the ionosphere," D. N. Anderson, M. J. Buonsanto, M. Codrescu, D. Decker, C. G. Fesen, T. J. Fuller-Rowell, B. W. Reinsich, P. G. Richards, R. G. Roble, R. W. Schunk, and J. J. Sojka, *J. Geophys. Res.*, 103, 2179, 1998.
 10. "Self-consistent simulation of the photoelectron-driven polar wind from 120 km to 9 R_E altitude," Y.-J. Su, J. L. Horwitz, G. R. Wilson, P. G. Richards, D. G. Brown, and C. W. Ho, *J. Geophys. Res.*, 103, 2279, 1998.
 11. "The November 1993 ionospheric storm: Comparison of observed and modeled response," P. G. Richards, P. J. Wilkinson, and K. L. Miller, *Adv. Space Res.* 20, (9), 1665, 1997.
 12. "Thermospheric neutral winds at southern mid-latitudes: comparison of optical and ionosonde $h_m F_2$ methods," P. L. Dyson, T. P. Davies, P. G. Richards, M. L. Parkinson, A. J. Reeves, and C. E. Fairchild, *J. Geophys. Res.*, 102, 27,189, 1997.
- "Equatorial plasma fountain and its effects over three locations: Evidence for an additional layer, the F_3 layer," N. Balan, G. J. Bailey, M. A. Abdu, K. I. Oyama, P. G. Richards, J. MacDougall, and I. S. Batista, *J. Geophys. Res.*, 102, 2047, 1997.